The High Impact of Astronomical Data Archives

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Executive Summary

Archives are widely recognized as a valuable resource for astronomy, but statistics on their use indicates they are even more important than most astronomers realize. Obviously much of the science from survey projects such as SDSS relies on the archive. Perhaps more surprisingly, archival data are also a major contributor to the science from targeted, PI-driven missions such as HST, Chandra, Spitzer and the ground-based observatories. Archival research currently accounts for half of the ~1200 Hubble and Chandra science papers published each year, and the use of the archive continues to increase. *The archival data products are, in the long term, as important as the PI science programs.*

It is vital to recognize the large impact archives can have on the science generated by missions and observatories. The value of the archive should be an important factor in the establishment of new projects. Future missions and observatories should not only budget adequate resources to support a robust archive, but they also should consider the effects of mission design and operations decisions on the archive. Additional funding both for archive users and archive centers – particularly with an eye to enabling cross-archive, multiwavelength science – is a relatively inexpensive way to increase the science output from our major investments in large projects.

How Important Are Archives?

Few would dispute the statement that archives can be a useful product for most astronomical missions and projects. But how important are they? Should we be putting more resources into improving our archives? Or should we focus our efforts (and budgets) on other operational and development activities and be satisfied with an archive that simply captures the results of those efforts?

Some current and planned science projects are built with a focus on the archive as the primary product. For example, the value of the Sloan Digital Sky Survey (SDSS) lies almost entirely in its creation a large homogeneous database that is suitable for a vast array of science projects, from studies of solar system asteroid families to the discovery of the most distant quasars in the universe. The SDSS project made many decisions about the telescope, instruments, operations, and data processing with an awareness of how those choices would affect the ultimate data archive. The science team relies on the archive, and the tools developed for the team are also made available to the community. The result is a highly successful project that has spawned an impressive quantity of archival research (more than 2200 refereed papers, most of which are authored by people outside the SDSS collaboration). The success of SDSS has led it to serve as a model for similar current and future projects such as GALEX and LSST.

Other types of projects are not obviously archive-driven at all. General-purpose observatories such as NOAO, Gemini, the VLA and NASA's Great Observatories (HST, Chandra, Spitzer) have heterogeneous science programs that are entirely defined by PI-led proposals. The science goals, instrument configurations, and resulting data characteristics vary widely.

Is the archive really used for such missions, or is its main role merely to enhance PI science by encouraging timely publication of (soon to be public) data? The answer to this question can affect many decisions about instrument design, data processing, and observatory operations. How much effort should be expended on creating standard calibrations and generating science-ready data products? Is work toward producing a more usable archive sufficiently important to justify reducing the effort on some other aspect of observatory operations?

The Science Impact of the Hubble and Chandra Archives

To shed light on these issues we have analyzed the impact of science using the HST and Chandra archives. We choose HST and Chandra not to make a point about those particular missions but because they are good exemplars: general-purpose observatories, driven by PI-led programs, for which we have very good statistics on publications and citations. These statistics are the best objective measure of the science impact of the mission.

The HST Archive

Since the HST launch in 1990, the STScI has maintained a database of refereed papers that utilized HST data. The database links publications in journals to the proposal that supplied the data. We have divided the data use in these papers into archival and non-archival using a conservative definition of archival data: data use is considered archival if none of the coauthors on the paper were co-investigators on the HST proposal that originally acquired the data. Even a single overlapping author/co-I leads to the data use being classified as non-archival. Clearly this does classify some truly archival uses of data as non-archival, because it is possible for scientists on the original proposal to reuse the data for new science many years after the observation.[1] So we expect that this definition slightly underestimates the number of archival papers.

A single paper may use data from several different HST proposals. This leads to classification of the papers into three groups: *Totally Archival* (all data are archival); *Non-archival* (none of the data are archival); and *Partially Archival* (data from multiple proposals were used, with some being archival and some non-archival).

Figure 1 shows the resulting publication rate for Hubble data papers from 1995 through 2008. Since 1997 the rate of non-archival PI science publications has remained steady (presumably because they are limited by the available telescope time). But over the entire 14-year period, there has been a continuous increase in the number of archival science papers. For the past 3 years (2006–2008), the number of totally archival papers has exceeded the number of non-archival papers.

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[1] A good example of that is the Riess et al. (2001, ApJ, 560, 49) discovery of a z=1.7 supernova in the HDF, which is classified as non-archival because some coauthors were on the original HDF NICMOS proposals that serendipitously observed the SN.

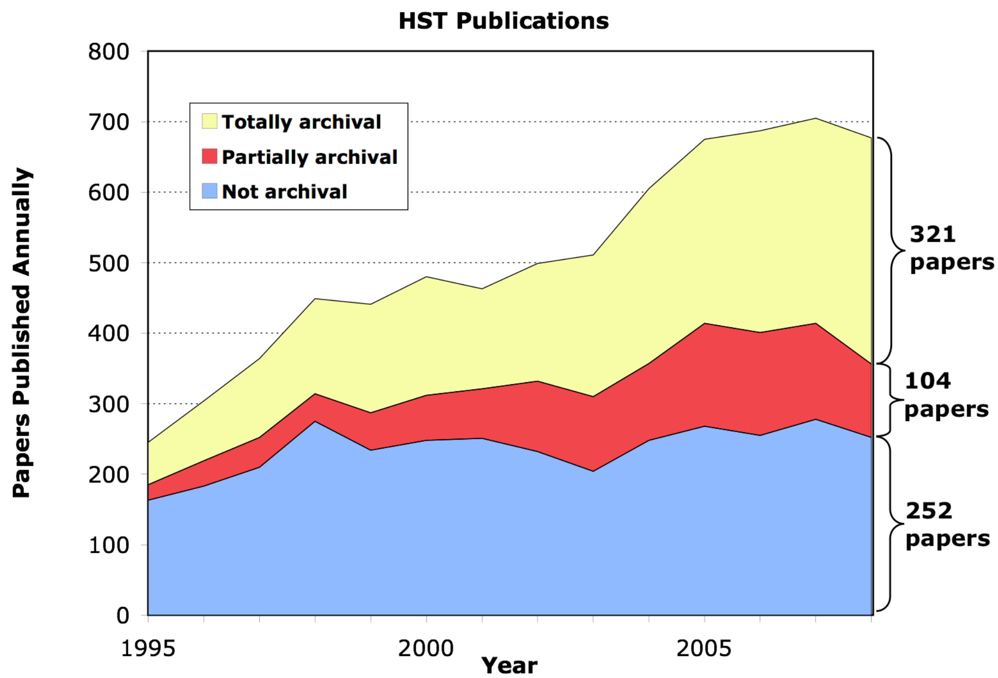

Figure 1: Number of annual publications using Hubble Telescope data. The publications have been divided into non-archival papers written by the original investigators (blue), totally archival publications not involving none of the original proposers (yellow), and papers that include data from multiple proposals with some being archival and some not (red). The number of archival papers has exceeded the number of PI-led papers since 2006.

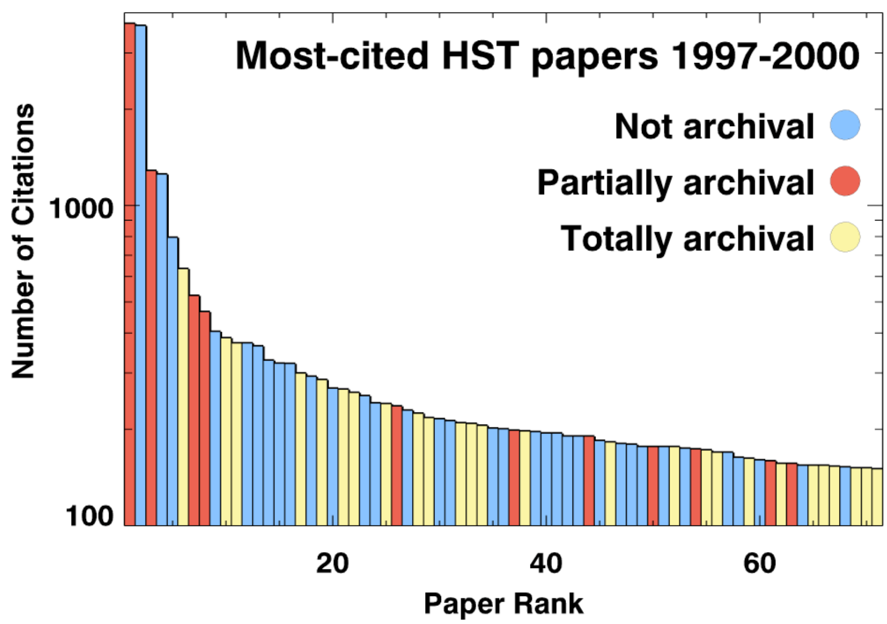

Figure 2: Highly cited HST publications between 1997 and 2000. All 71 papers with more than 150 citations (as of March 2009) are included in the sample. Note the *y*-axis is logarithmic. As in Figure 1, the publications have been divided into non-archival (blue), totally archival (yellow), and partially archival (red) depending on whether the original proposers were authors on the paper. Totally archival papers make up 37% of the highly cited sample, which is slightly above the rate expected based on their frequency of publication during this period.

Analysis of the impact of archival and non-archival papers, as measured by citations, shows that archival papers have an impact similar to non-archival publications. They are not merely cleaning up the scraps left behind after the PI science was completed. Figure 2 shows the number of citations for the most highly cited HST papers published between 1997 and 2000. This time interval was chosen because it has a significant number of archival papers and is far enough in the past for papers to have accumulated a substantial number of citations. The complete list of papers is included in Appendix 1. For the highly cited papers, 37% are totally archival, 15% are partially archival, and 48% are non-archival. For comparison, the corresponding fractions for all HST papers published during 1997–2000 were 33%, 11%, and 56%, respectively. Thus archival papers are represented among the highly cited papers at the frequency expected based on their publication rates. Summing the citations in the different categories shows that totally, partially, and non-archival papers account for 23%, 28% and 49% respectively of the citations. These numbers are obviously skewed by the top-cited partially archival paper but nonetheless represent a very respectable showing for archival research. It is clear that archival papers are very well represented among even the most highly cited HST mission papers. *Archival science is high-impact science.*

Finally, the usage of the HST archive continues to increase. The growing number of archive publications is apparent in Figure 1: between 2004 and 2008 the annual number of totally archival publications increased 30% (7% per year). Over the same period, the number of archive searches increased by 70%, with searches through VO-compatible interfaces now making a substantial contribution. All indications are that *archival research will be even more dominant in the years to come.*

The Chandra Archive

The Chandra X-ray Observatory, launched in 1999, has a shorter history than Hubble but shows publication and citation trends that are completely consistent with those described above. The Chandra archive also tracks publications and citations associated with their data, and we have similarly divided those publications into non-archival, partially archival, and totally archival categories. The definitions of these categories are somewhat different than those used for Hubble: dataset usage is identified as archival as long as the PI and prime observer are not coauthors (so publications with Co-Is but not the PI are counted as archival), and data papers identified as follow-up science are assigned to the partially archival category. These differences have some effect on the counts in the categories, but for the great majority of papers they would result in the same classification as used for HST.

Figure 3 shows the publication rate for Chandra data papers from 2000 through 2008. The similarity to the HST history (Fig. 1) is striking, with recent Chandra publications being even more heavily dominated by archival science. Obviously the Hubble archival experience is not an anomaly. As Chandra approaches its tenth anniversary, it is clear that its long term its archival science productivity will exceed that of the PI programs.

The analysis of highly cited Chandra papers is shown in Figure 4. The time window chosen, 2001–2003, is necessarily more recent than that used for HST. The selected papers are listed in Appendix 2. For the highly cited papers, 27% are totally archival, 19% are partially archival, and 54% are non-archival. For comparison, the corresponding fractions for all Chandra papers published during 2001–2003 were 34%, 12%, and 54%, respectively. Note that at the beginning of this period, Chandra had been in orbit only 1.5 years, so the archive held very little non-proprietary data; consequently there were relatively few archival papers in 2001 (Fig. 1). Nonetheless, for Chandra as for HST, archival papers are very common among the observatory's highest impact papers.

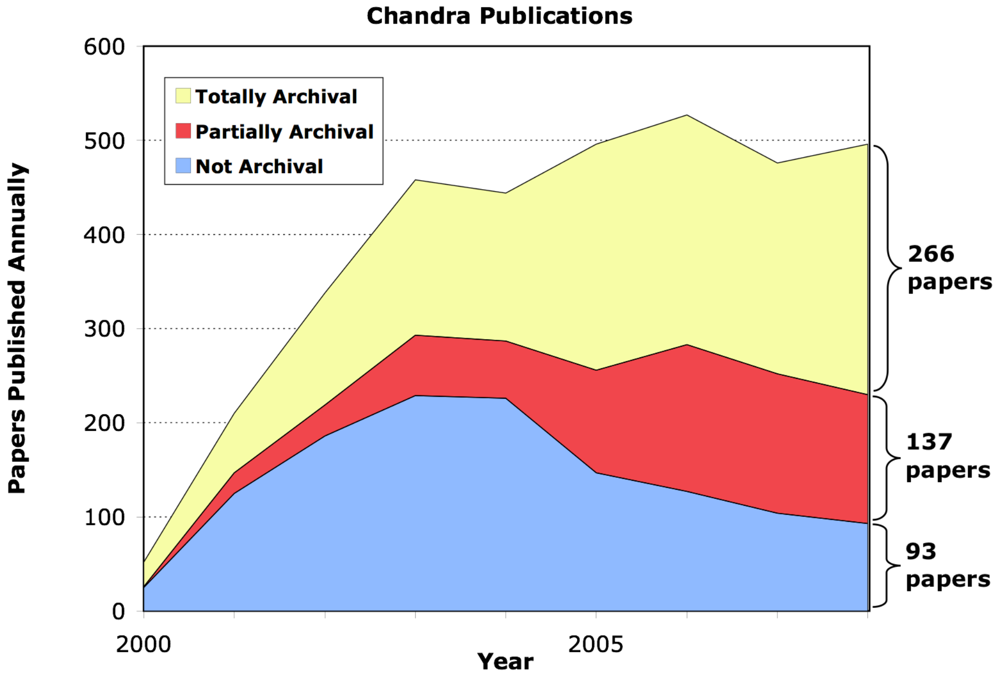

Figure 3: Number of annual publications using Chandra Observatory data. As for HST, the publications have been divided into non-archival (blue), totally archival (yellow), and partially archival papers (red). The definition of the "Totally Archival" category is slightly less conservative than the one used for the HST plot, but the trend is clear: archival science dominates PI-led science for Chandra as well.

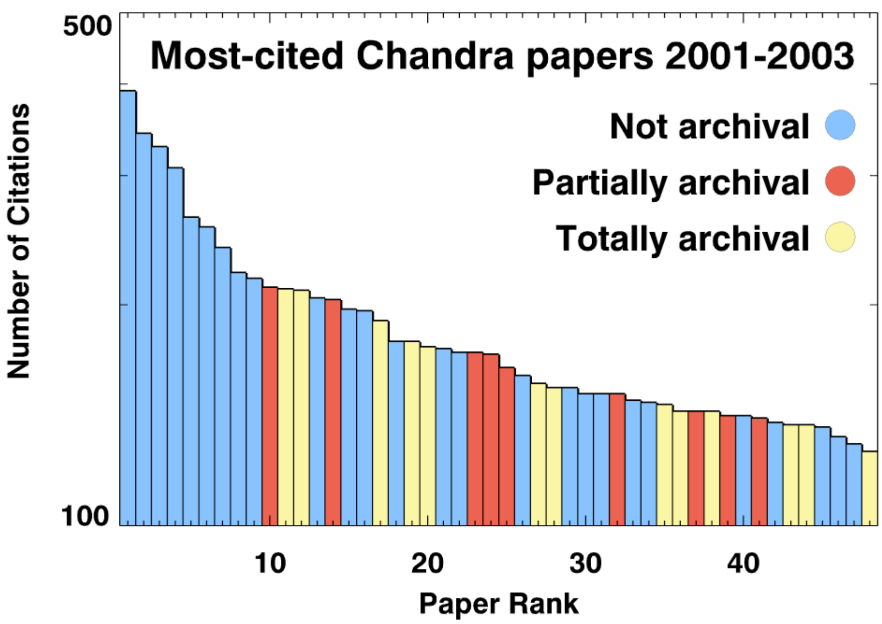

Figure 4: Highly cited Chandra publications between 2001 and 2003. All 48 papers with more than 125 citations (as of March 2009) are included in the sample. Note the *y*-axis is logarithmic. As in Figure 3, the publications have been divided into non-archival (blue), totally archival (yellow), and partially archival (red). Totally archival papers make up 27% of the highly cited sample, which is consistent with their 34% frequency among all publications from this period.

Summary

This is a remarkable result. Hubble and Chandra remain cutting-edge facilities that are heavily oversubscribed with new science proposals, and few of their observing programs have been created primarily to facilitate archive science. (The principal exceptions are the Hubble Deep Fields, which were born as archival products.) Nonetheless, fully half of the science with Hubble and Chandra now relies on archival data. This can be attributed both to well-established infrastructures for supporting the archives and to the sheer longevity of these missions, which each year add one year's worth of new data but already hold one to two decades of existing data. All the trends indicate that archival science will become increasingly dominant as time passes. The bottom line: *Even for missions that are based essentially entirely on a heterogeneous collection of PI proposals, archival research dominates the PI-led science for the observatory.*

The Science Impact of Data Integration Services

Services that integrate information from the astronomical literature and from observatory and sky survey archives are also important components of the framework of modern astrophysics research. As an example, the NASA/IPAC Extragalactic Database (NED) provides data from hundreds of large sky surveys and tens of thousands of research publications spanning the spectrum from gamma rays through radio frequencies. As of March 2009, NED provides information for 163 million objects with connections to the literature via the ADS and to relevant data centers around the world. NED also provides services such as name-to-coordinate resolution and access to object data that are widely used by other archives, including observation planning tools such as SPOT (Spitzer) and APT (HST) and image analysis tools such as Aladin (CDS

As for the mission archives, the science impact of NED and other integrative services can be measured via citations and acknowledgements in the astrophysics literature. Figure 5 shows the annual citations and acknowledgments to NED from 1991 through 2008. Over the period 2004 through 2008, NED was cited in an average of 470 articles per year, which is about 18% of all journal articles on extragalactic topics.

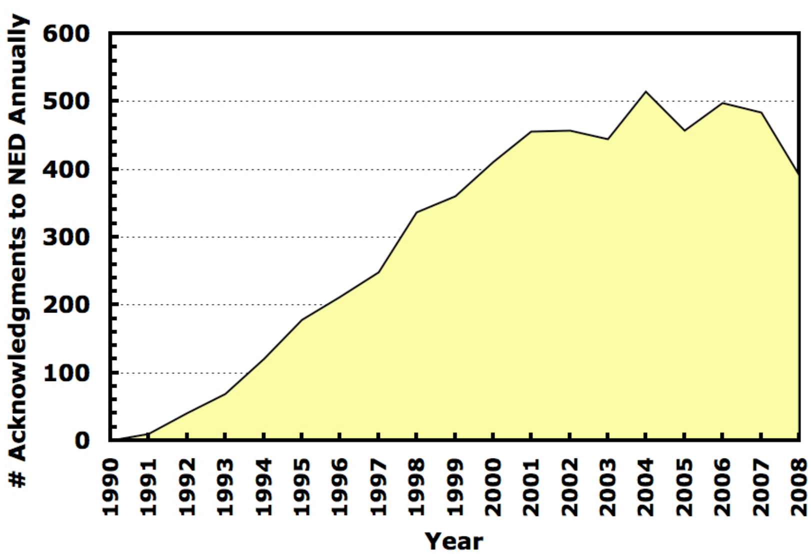

Figure 5: Annual acknowledgments to NED in the literature from 1991 through 2008.

Recommendations to Maximize the Impact of Archival Science

Archival science is a relatively inexpensive way to increase the science output of large missions and projects. Archives are obviously the principal focus for surveys such as SDSS, but the statistics above demonstrate that they are also of key (and increasing) importance for pointed missions such as Hubble, Chandra, and, presumably, Spitzer and the national observatories.

Maximizing the impact of archival science should be an explicit goal of missions and projects over the coming decade.

1. *Ensure sufficient funding and support for researchers making use of the archives.*

Future projects such as ALMA and LSST will require greater user resources for effective utilization of the trove of data they generate. A broad-based community science program using these data is likely to require additional funding both for archive users and for the archive centers. (Note that the level of funding required is invariably modest compared with the cost of acquiring the data.) In addition to funding the hardware and software required for data analysis, resources are needed to train the astronomical community in the use of archives. Astronomy departments should be provided the means and incentive to put archival science into their core graduate curricula, and the national facilities should provide a continuing series of summer schools to educate the next generation of astronomers. These will be similar to the successful NVO summer schools but will include a broader range of topics including, for example, the use of more powerful statistical techniques and packages.

Multiwavelength studies that draw data from multiple archives are an increasingly important theme in astronomy. The Virtual Astrophysical Observatory will provide the tools and protocols to facilitate this research, but fully utilizing these capabilities will require additional resources. The funding process for archival research should support the needs of cross-archive research, both for the scientists and for the archive centers (including integrative archive services such as ADS, NED, Vizier, etc.).

2. *Ensure that current and future observatories and missions make their data available in science-ready form and with appropriate documentation.*

The importance of archival science implies that establishing an archive should be a primary goal of new missions and observatories. In fact, we believe that the ultimate value of the archive should be an important factor in the establishment of new projects.

Existing projects should continue their efforts to improve their archives. The space-based observatories have generally made good progress in creating user-friendly archives containing their datasets. This is at least partly due to the close control and tracking of the commands that are sent to orbiting telescopes, which leads to the capture of detailed metadata describing the observer's intent and execution of the program. Ground-based observatories have a less-controlled environment, which can make generating high-level data products more difficult (though this is changing with the advent of queue scheduling). But it is very likely that with improved functionality and higher level data products, the research done from ground-based archives could be greatly increased to a level commensurate with that of PI programs. The effort required to create data processing pipelines that generate high quality, science-ready data products will likely exceed the resources currently available at the archive centers, but our experience is that an investment in this area will be amply repaid in science. To this end it would be helpful to have projects focused solely on improving the archives, with independent funding that is not subject to redirection to other observatory priorities.

As the archive data holdings and usage both increase in volume, the archive centers will need to upgrade their infrastructure. While Moore's law will solve many problems, some important aspects (such as network bandwidth) are likely to require additional investments to avoid becoming a bottleneck for researchers.

3. *The fact that a good fraction of all science from missions will ultimately be archival should be taken into consideration in all phases of mission/observatory design and operations. The archival data products are, in the long term, as important as the PI science programs!*

Future missions should not only budget adequate resources to support a robust archive, but they also should consider the effects of mission design decisions on the archive. Even missions that focus on a singular prime science goal (e.g., JDEM's characterization of the physics of dark matter) will potentially generate a body of data that ultimately has an impact on science comparable to the prime science. The long-term archival impact of decisions should be an important factor that is weighed in all phases of the mission design and operations. This same trade-off is made in allocating telescope time for general-purpose observatories, and many observatories have already recognized the value of collecting the best archival data through the establishment of treasury, legacy, and other similar large observing programs.

Note that better archival data can also improve the prime mission science. A JDEM archival research program studying galaxies and large scale structure may well turn up improved algorithms for measuring dark matter parameters, e.g., by separating galaxies by morphological class. Mission decisions that make the archive less useful reduce the chances of the feedback that is the hallmark of scientific inquiry.

Appendix 1: Most Highly Cited HST Publications from 1997–2000

Below are listed the 71 HST papers published between 1997 and 2000 that were most highly cited as of March 2009. All papers with 150 or more citations are listed. The first column gives the number of citations, the second the type of paper (totally archival, partially archival, or not archival) and the remainder the reference. These are the data used for Figure 2.

#Cite	Archival?	Bibcode	Author	Title
3701	Part	1999ApJ...517..565P	Perlmutter, S.	Measurements of Omega and Lambda from 42 High-Redshift Su...
3643	Not	1998AJ....116.1009R	Riess, A. G.	Observational Evidence from Supernovae for an Acceleratin...
1284	Part	1998AJ....115.2285M	Magorrian, J.	The Demography of Massive Dark Objects in Galaxy Centers
1252	Not	2000ApJ...539L..13G	Gebhardt, K.	A Relationship between Nuclear Black Hole Mass and Galaxy...
793	Not	1998Natur.391...51P	Perlmutter, S.	Discovery of a Supernova Explosion at Half the Age of the...
633	Total	1997ApJ...483..565P	Perlmutter, S.	Measurements of the Cosmological Parameters Omega and Lam...
522	Part	1997ApJ...490..577D	Dressler, A.	Evolution since Z = 0.5 of the Morphology-Density Relatio...
465	Part	1997AJ....114.1771F	Faber, S. M.	The centers of early-type galaxies with HST. IV. Central ...
403	Not	1998ApJ...509...74G	Garnavich, P. M.	Supernova Limits on the Cosmic Equation of State
385	Total	1998ApJ...492..461S	Stanford, S. A.	The Evolution of Early-Type Galaxies in Distant Clusters
371	Total	1997ApJ...481..673L	Lowenthal, J. D.	Keck Spectroscopy of Redshift Z approximately 3 Galaxies ...
371	Not	1997ApJ...486L..11C	Connolly, A. J.	The evolution of the global star formation history as mea...
363	Not	1998ApJ...493L..53G	Garnavich, P. M.	Constraints on Cosmological Models from Hubble Space Tele...
328	Not	1999AJ....118.1551W	Whitmore, B. C.	The Luminosity Function of Young Star Clusters in `the An...
321	Not	1997ApJ...483..582E	Ellis, R. S.	The homogeneity of spheroidal populations in distant clus...
320	Not	1997ApJ...479..642B	Bahcall, J. N.	Hubble Space Telescope images of a sample of 20 nearby lu...
299	Total	1997ApJ...475..469Z	Zheng, W.	A composite HST spectrum of quasars
292	Not	1998ApJS..117...25M	Malkan, M. A.	A Hubble Space Telescope Imaging Survey of Nearby Active ...
285	Total	1999ApJ...513...34F	Fernandez-Soto, A.	A New Catalog of Photometric Redshifts in the Hubble Deep...
268	Not	1998ApJ...508..539P	Pettini, M.	Infrared Observations of Nebular Emission Lines from Gala...
266	Total	1999ApJ...521...64M	Meurer, G. R.	Dust Absorption and the Ultraviolet Luminosity Density at...
260	Total	1999ApJ...511..639I	Izotov, Y. I.	Heavy-Element Abundances in Blue Compact Galaxies
254	Not	1998ApJ...493..180M	Massey, P.	Star Formation in R136: a Cluster of O3 Stars Revealed by...
241	Not	1998ApJ...493..222M	Meyer, D. M.	The Definitive Abundance of Interstellar Oxygen
240	Total	1998MNRAS.298..583I	Ivison, R.J.	A Hyperluminous Galaxy at z = 2.8 Found in a Deep Submill...
236	Part	1997AJ....114...54M	Meurer, G. R.	The panchromatic starburst intensity limit at low and hig...
229	Not	1999MNRAS.308..377M	McLure, R. J.	A Comparative HST Imaging Study of the Host Galaxies of R...
224	Total	1997ARA&A..35....1D	Davidson, K.	Eta Carinae and Its Environment
217	Total	1998ApJ...504L..17V	van Dokkum, P. G.	Luminosity Evolution of Early-Type Galaxies to z = 0.83: ...
215	Not	1997ApJ...489..579M	Macchetto, F.	The supermassive black hole of M87 and the kinematics of ...
212	Not	1998ApJ...497..188C	Couch, W. J.	Morphological Studies of the Galaxy Populations in Distan...
209	Total	2000PASP..112.1383D	Dolphin, A. E.	WFPC2 Stellar Photometry with HSTPHOT
208	Total	1997AJ....113....1S	Sawicki, M. J.	Evolution of the galaxy population based on photometric r...
205	Total	2000AJ....119.2092B	Barger, A. J.	Mapping the Evolution of High-Redshift Dusty Galaxies wit...
201	Not	1998AJ....116.1357S	Sahai, R.	Multipolar Bubbles and Jets in Low-Excitation Planetary N...
200	Not	1998ApJ...500...75L	Lilly, S.	Hubble Space Telescope Imaging of the CFRS and LDSS Redsh...
198	Part	1999ApJ...516..750C	Crenshaw, D. M.	Intrinsic Absorption Lines in Seyfert 1 Galaxies. I. Ultr...
197	Total	1999ApJ...510..576P	Pettini, M.	Metal Abundances at z < 1.5: Fresh Clues to the Chemical ...
196	Not	1997A&A...321..733L	Le Brun, V.	The nature of intermediate-redshift damped Ly alpha absor...
194	Not	1999ApJ...525..750F	Figer, D. F.	Hubble Space Telescope/NICMOS Observations of Massive Ste...
194	Not	2000AJ....119..991S	Scoville, N. Z.	NICMOS Imaging of Infrared-Luminous Galaxies
190	Not	1997ApJ...486L..75F	Franx, M.	A pair of lensed galaxies at z=4.92 in the field of CL 13...
190	Not	2000ApJ...529..786M	Mould, J. R.	The Hubble Space Telescope Key Project on the Extragalact...
190	Part	2000ApJS..130....1R	Rao, S. M.	Discovery of Damped Ly alpha Systems at Redshits Less Tha...
184	Not	2000MNRAS.311..565L	Le Fevre, O.	Hubble Space Telescope imaging of the CFRS and LDSS redsh...
182	Total	1998ApJ...503L.131S	Stanek, K. Z.	Distance to M31 with the Hubble Space Telescope and HIPPA...
180	Not	1997ApJ...482..114H	Heckman, T. M.	A powerful nuclear starburst in the Seyfert galaxy Markar...
179	Not	1998ApJ...499..758J	Johnstone, D.	Photoevaporation of Disks and Clumps by Nearby Massive St...
176	Not	1997ApJ...484L..25R	Rich, R. M.	Discovery of extended blue horizontal branches in two met...
176	Part	1998ApJ...499..112B	Brinchmann, J.	Hubble Space Telescope Imaging of the CFRS and LDSS Redsh...
176	Not	2000ApJ...541...95V	van Dokkum, P. G.	Hubble Space Telescope Photometry and Keck Spectroscopy o...
176	Total	2000PASP..112.1397D	Dolphin, A. E.	The Charge-Transfer Efficiency and Calibration of WFPC2
174	Not	2000ApJ...540.1016L	Luhman, K. L.	The Initial Mass Function of Low-Mass Stars and Brown Dwa...
173	Part	1999ApJ...520L..95V	van Dokkum, P. G.	A High Merger Fraction in the Rich Cluster MS 1054-03 at ...
172	Total	1997ApJ...489..559G	Guzman, R.	The Nature of Compact Galaxies in the Hubble Deep Field. ...
169	Total	1997ApJ...482..913G	Gould, A.	M dwarfs from Hubble Space Telescope star counts. III. Th...
169	Not	1998ApJ...498..181K	Kennicutt, R. C.	The Hubble Space Telescope Key Project on the Extragalact...
163	Not	2000ApJ...534L...1T	Tripp, T. M.	Intervening O VI Quasar Absorption Systems at Low Redshif...
162	Total	1997A&A...327.1054B	Baraffe, I.	Evolutionary models for metal-poor low-mass stars. Lower ...
160	Not	1997AJ....113.2246R	Reid, I. N.	Low-mass binaries and the stellar luminosity function
159	Part	2000MNRAS.312L...9M	Madau, P.	Deep Galaxy Counts, Extragalactic Background Light and th...
156	Total	1998AJ....116.1039R	Richards, E. A.	Radio Emission from Galaxies in the Hubble Deep Field
156	Part	2000AJ....119.2919B	Bally, J.	Disks, Microjets, Windblown Bubbles, and Outflows in the ...
154	Not	1999AJ....117.1490P	Padgett, D. L.	Hubble Space Telescope/NICMOS Imaging of Disks and Envelo...
154	Total	1999ApJ...519L..13F	Fruchter, A. S.	Hubble Space Telescope and Palomar Imaging of GRB 990123:...
154	Total	1999ApJ...527L..81Z	Zhang, Q.	The Mass Function of Young Star Clusters in the `Antennae...
153	Total	2000ApJ...528..637B	Brandt, W. N.	On the Nature of Soft X-Ray Weak Quasi-Stellar Objects
152	Not	1998AJ....116...68C	Carollo, C. M.	Spiral Galaxies with WFPC2. II. The Nuclear Properties of...
151	Total	1997ApJ...479L.121V	Vogt, N. P.	Optical rotation curves of distant field galaxies: sub-L[...
151	Total	1999A&A...349...77C	Chiaberge, M.	The HST View of FR I Radio Galaxies: Evidence for Non-the...
150	Total	1998AJ....115.1319C	Cowie, L. L.	High-z Lyalpha Emitters. I. A Blank-Field Search for Obje...

Appendix 2: Most Highly Cited Chandra Publications from 2001–2003

Below are listed the 48 Chandra papers published between 2001 and 2003 that were most highly cited as of March 2009. All papers with 125 or more citations are listed. The first column gives the number of citations, the second the type of paper (totally archival, partially archival, or not archival) and the remainder the reference. These are the data used for Figure 4.

#Cite	Archival?	Bibcode	Author	Title
391	Not	2003ApJ...598..886U	Ueda, Y.	Cosmological Evolution of the Hard X-Ray Active Galactic ...
342	Not	2003AJ....126..539A	Alexander, D. M.	The Chandra Deep Field North Survey. XIII. 2 Ms Point-Sou...
328	Not	2001ApJ...551..624G	Giacconi, R.	First Results from the X-Ray and Optical Survey of the Ch...
307	Not	2002ApJS..139..369G	Giacconi, R.	Chandra Deep Field South: The 1 Ms Catalog
263	Not	2001AJ....122.2810B	Brandt, W. N.	The Chandra Deep Field North Survey. V. 1 Ms Source Catalogs
255	Not	2002ApJ...566..667R	Rosati, P.	The Chandra Deep Field-South: The 1 Million Second Exposure
239	Not	2003ApJ...591..891B	Baganoff, F. K.	Chandra X-Ray Spectroscopic Imaging of Sagittarius A* and...
221	Not	2003MNRAS.344L..43F	Fabian, A. C.	A deep Chandra observation of the Perseus cluster: shocks...
217	Not	2001Natur.413...45B	Baganoff, F. K.	Rapid X-ray flaring from the direction of the supermassiv...
211	Part	2002A&A...384..848E	Elbaz, D.	The bulk of the cosmic infrared background resolved by IS...
210	Total	2001ApJ...557..546D	David, L. P.	A High-Resolution Study of the Hydra A Cluster with Chand...
209	Total	2001A&A...366..407G	Gilli, R.	Testing current synthesis models of the X-ray background
204	Not	2003AJ....126..632B	Barger, A. J.	Optical and Infrared Properties of the 2 Ms Chandra Deep ...
203	Part	2003MNRAS.344...60G	Gallo, E.	A universal radio-X-ray correlation in low/hard state bla...
197	Not	2001AJ....121..662B	Barger, A. J.	The Nature of the Hard X-Ray Background Sources: Optical,...
196	Not	2001ApJ...551..160V	Vikhlinin, A.	A Moving Cold Front in the Intergalactic Medium of A3667
190	Total	2002MNRAS.337....1I	Ivison, R. J.	Deep radio imaging of the SCUBA 8-mJy survey fields: subm...
178	Not	2002ApJ...571..218N	Norman, C.	A Classic Type 2 QSO
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